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THE PALEOENVIRONMENT OF THE LOWER MISSISSIPPI RIVER DELTA DURING THE LATE HOLOCENE

by

SIMMONE SIMPSON

Under the Direction of Dr. Lawrence Kiage

ABSTRACT

Palynological, lithological, loss-on-ignition, and X-ray fluorescence spectroscopy data were collected from a modified Livingstone core retrieved from Bay Jimmy, Louisiana. This data indicates a slow, general regression of the marsh due to sea level rise. This trend was punctuated by several catastrophic events including floods from around ca. 600 Yr BP and ca. 360 Yr BP, a fire around ca. 950 Yr BP, and still more flooding caused by the landfall of Hurricane Audrey in AD 1957, and Hurricanes Katrina and Rita in AD 2005. In more recent years (220 Yr BP to present) the marsh appears to have thinned out. This may be due to anthropogenic barriers, which have inhibited the marsh's natural retreat as witnessed over the past 1200 years recorded by this core.

INDEX WORDS: Palynology, Mississippi River Delta, Climate, Paleotempestology, Louisiana, Paleoenvironmental reconstruction

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by

SIMMONE SIMPSON

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of

Master of Science

in the College of Arts and Sciences

Georgia State University

2013

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2013

THE PALEOENVIRONMENT OF THE LOWER MISSISSIPPI RIVER DELTA DURING THE LATE HOLOCENE

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Electronic Version Approved:

Office of Graduate Studies

College of Arts and Sciences

Georgia State University

December 2013

DEDICATION

I dedicate my thesis to the Geosciences Department. Graduate students and faculty have assisted me with my nearly neurotic questions and worries. I hope this thesis serves as a basis of knowledge for me to create new studies from. I also hope that those studies will reflect the caliber of this department and help maintain a positive reputation for Georgia State University.

ACKNOWLEDGEMENTS

I would like to thank Dr. Kiage, my advisor, for guiding me into a thesis idea and providing me with the cores from his work in Louisiana. I would also like to thank Erick Braun and Daniel McCartha for lending me their knowledge on XRF data, graph formation, and to Daniel specifically for his quick and diligent work on my cores. The Department of Geosciences at Georgia State assisted me with bits of help and information along the way. Dr. Meyer is awarded particular thanks for coming to my lab and personally inspecting my cores and providing me with names of researchers and their studies that I could search.

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1 INTRODUCTION

Uniformitarianism, the idea that processes today are likely how processes operated in the past, has a long standing history in geology. By mapping the progression of plant communities through time, we are able to see how the environment changed in the past. In turn, scientists today can make better predictions of how the environment will respond in future to natural and anthropogenic climate change. Changes in the stratigraphy of sediment cores recovered from Bay Jimmy can provide important information regarding the paleoenvironment of the deltaic coast in Louisiana.

Economically, the reconstruction of paleoenvironments can be quite valuable. Oil and gas production companies use pollen and spores to correlate freshwater and marine sediments, and certain taxa assemblages can indicate that particular rock strata may be a source for petroleum (Gutjahr 1960; Pearsall and Piperno 1993; Jahn et al 1998). Reconstructing paleoenvironments can also assist in interpreting the time periods at which tempest events occurred in the past, providing data for the calculation of the recurrence intervals for tempest events (Liu, 2004a). This can assist insurance companies and government agencies in setting aside the appropriate funds and resources for future events.

1.1 How to Interpret Paleoenvironments

Pollen plays a significant role in paleoenvironmental reconstruction. Birks and Birks (1980) explain that there are several basic assumptions taken when studying fossil pollen in paleoenvironments, which are: that current ecological knowledge is valid, that current plant communities are at an equilibrium point when compared to their fellow plants and factors for life, that the paleoenvironments being studied were also at equilibrium, and that same plant species function the same in the past as they do in the present.

With these assumptions in place we are able to extract information about what environment must have been conducive for the plant life represented. The pollen is deposited in layers just as any other fossil. Researchers are then able to use the principle of fossil succession and superposition to show the change of vegetation, and therefore environment and climate, over time at the study location. Assemblages are used to show relative proportions of plant species; this assists with indicating what the environment looked like at a given time and also its change over time.

There are several other means of conducting paleoenvironmental and paleoclimatic reconstruction; these include, but are not limited to the use of paleosols, diatoms, phytoliths, isotopic ratios, fossilized eggshells and teeth, and foraminifera (Stillwell and Feldman 2000; Wei et al 2003; Sheldon and Tabor 2009; Manchester et al 2012; Monotanari et al 2013). Paleosols, or ancient soils, can be quite useful as they also represent the environment at the time of sediment and pollen deposition (Sheldon and Tabor 2009). Paleosols and fossil pollen are synergistic in use, as visible presence of changing layers, or changing in pollen types, helps to corroborate the environmental history for a core.

XRF (X-ray fluorescence) data are often used in conjunction with pollen data for both the purpose of dating and interpreting paleoenvironments. In this process, described by Wirth (2013), atoms are excited within the sediment causing them to release an electron and change energy states. Each element releases a unique amount of energy due to this excitement, and the energy that returns to the receiver allows the instrument to interpret these concentrations in parts per million (ppm). The concentrations of different elements in sediment can tell a wide variety of things about a paleoenvironment. For example, relative increases in elements such as chlorine and sulfur may represent inundation by seawater, while elements such as titanium, potassium, and iron tend may represent some input from a terrestrial setting (Liu and McCloskey 2012; Wei et al 2003; Woodruff et al 2008). In addition, some studies such as the one done by Meyer (2013) have catalogued different environments based off of chemofacies (elemental concentrations). Comparisons of XRF data to these sorts of studies may help further determine the nature of a particular environment. XRF data may also help in determining the relative ages of certain sedimentation. For example, anthropogenic causes for high lead concentrations that appear in sediment during the 1800's are well documented (Donnelly and Webb 2004); therefore, if high lead concentrations are found in the sediment, and are sustained, this may be an indicator that the core is now representing a post-1800 time period.

When using pollen to detect tempest events, the presence of sciophytic (shade-loving) plants, interrupted abruptly by heliophytic (sun-loving) plants, could be a strong indicator of disturbance. If the core is taken in a back-barrier freshwater lake, the presence of salt intolerant plants, succeeded by plants which thrive in saline environments, could also be a strong indicator of a tempest event. Conducting LOI (loss on ignition) analysis, the process of heating sediment at various temperatures and weighing it to see how much is burned off, is used to determine the likelihood of a cyclonic event. There are several methods for conducting loss on ignition; generally, a crucible is packed with one gram of sediment and heated 105°C for two hours and weighed before and after to get a percentage of mass lost to water (Chilingar 1967). The next stage, the burning off of organics has variable techniques, one of which is heating the sample to 350°C for seven to eight hours or 550°C for one hour (Jackson 2005; Williams 2013). The last step, burning of carbonate material, is uniform across many studies; the sediment burned at 1,000°C for one hour and weighed before and after, as in the previous steps. This sort of analysis enables a researcher to detect sand layers that may not be readily visible, disturbance of vegetation, and various changes in lithology (Liu 2004b). Combining LOI with pollen analysis and XRF data assists with developing as complete a picture as possible of the environment at the time of the possible cyclonic event (Liu 2004b; Webb and Donnelley 2004).

It is knowledge of previous plant life that allows researchers to make inferences about prevailing paleoclimates and paleoenvironments. This information is able to be extrapolated because all plants have specific requirements for life. Biogeography is a field that is necessary to, at least, minimally understand in order to use pollen data properly. Biogeography is the study of plants and animals in relation to their diversity and patterns of distribution. In essence, it is the job of a researcher in the field of paleoenvironmental reconstruction to use biogeography in reverse; instead of studying the environments that a plant is found in, the researcher would study what plants were there to know what the environment was like.

While some plants may have a rather broad range of environmental conditions under which they can live, there are many plants that have narrow ranges of acceptable habitat: these specifications of soil, sunlight, and water are known as limiting factors. An example of a limiting factor might be the need for Serpentine soils—soils that are derived from ultramafic rocks and generally have low calcium to magnesium ratios—a requirement for the flower *Phlox hirsuta* (Calflora 2013). Though serpentine soils are not particularly useful for paleoclimate knowledge, endemic (existing in a narrow range) plants, like *Phlox* can be useful for determining environmental conditions, such as elevation. Plant species that are utilized for specific environmental markers are known as indicator species. Hydrangea, for example, is highly tolerant to erosion and would be competitive in an environment where other plants find it difficult to take root (Carter 2005).

Some common genera found in the Mississippi River Delta include *Quercus, Salix, Taxodium, Ilex, Fraxinus, Acer, Ulmus,* and *Liquidamber* (Reese and Liu 2001). Another study by Delcourt and Delcourt (1996) indicated the presence of *Ilex, Ambrosia,* Amaranthaceae, and Chenopodiaceae as well as Cupressaceae for wet, lowland swamps. *Pinus* pollen is still another genus that is expected to be found in the Lower Mississippi River Valley, but it is not indicative of a marsh environment as it is readily subject to long distance transport (Delcourt and Delcourt 1996). Gramineae would be expected as well because the delta is dominated by sawgrass marsh (Biber et al. 2012).

1.2 Pollen Identification

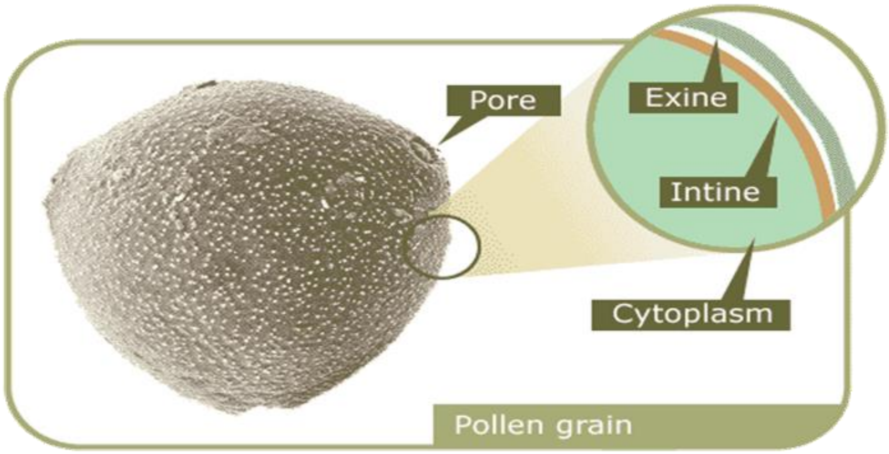

Figure 1.1 Basic Anatomy of a Pollen Grain ("Pollen and Allergy Introduction" 2013)

Pollen is a fine grain that is produced by the anther of a plant; its purpose is to reach the pistil of a plant that is the same plant type for fertilization (Faegri and Iverson 1964). Its structure, shown in figure 1.1, is designed to provide nourishment for the protoplasm (living portion) in the intine, which is mostly comprised of cellulose. The exine is the tough outer portion of pollen, which is comprised of sporopollenin, and provides protection for the grain (Kapp 1969). The readily oxidized grains have a short time-frame of viability before they begin to deteriorate and require an anoxic environment to preserve the exine (Kapp 1969; Faegri and Iverson 1964).

The exine of pollen grains functions as fingerprint; the unique and varied physical attributes of pollen grains enables different genera to be readily identified. Under the microscope, pores (openings on the exine) and colpi (furrows) are visible and utilized for floral identification. Pollen grains encompass an entire range of external textures, from inaperturate (no visible pores) to many pores (polyporate); for example a single-pore grain (known as monoporate) that is annulate and with a smooth exterior (psilate) is a good indicator that one is looking at a type of Gramineae (Kapp 1969). Colpi exhibit a full range of occurrences, from a lack of presence, known as acolpate, to many colpi, known as polycolpate (Kapp 1969). Other types contain both colpi and pores e.g. monocolporates, polycolporates etc.

Other physical features are important, but play a secondary role in identification. Most pollen keys will begin to narrow the options down with pores and colpi first. This is likely due to the varying shapes that are present for the same pollen grain depending on the angle that is visible. It is also a common occurrence for pollen and spores to become folded and appear to have a different shape. Surface texture is a highly defining feature, but is nearly impossible to detect without a high power microscope. The textures come in various forms of patterned concave features (Striate, Rugulate, or Reticulate) or patterned convex features; the convex features range from a rounded texture known as Scabrate to a sharp texture known as Echinate. Lastly, size can be helpful when trying to choose between two similar looking grains. This is generally taken as a last resort, as it can be difficult to obtain a measurement without an ocular piece designed with a scale in it.

Though size plays a minor role in identification of a pollen grain, the fact that pollen grains are all relatively small makes it incredibly useful for obtaining data. Most pollen grains are smaller than 100 micrometers. This makes it possible for very little sediment to be used; one cubic centimeter is quite common for pollen processing. This is important for many reasons; the remaining sediment for a given centimeter of length can be used for other forms of processing, which include, but are not limited to: XRF (X-ray fluorescence), for chemical processing, and radiometric dating.

1.3 Use of Pollen and Spores for Paleoenvironmental Reconstruction

Paleoenvironmental reconstruction is the process of sampling and studying sediment to determine environmental changes through time (Sheldon and Tabor 2009). In contrast to reconstructing paleoclimates, paleoenvironments do not represent solely meteorological conditions, but rather all of the factors that generated the environment. Paleoclimatic reconstruction looks for broad changes in climate at decadal, centennial, and millennial scales; this could be exemplified by finding data that indicates a gradual drying of a region, or a sign of cyclical glaciation for the site in question (Dowsett et al 1999).

Pollen is useful for paleoenvironmental studies for reasons beyond its physical appearance. Because pollen is necessary for the continuance of a species, it tends to be produced in vast quantities. This is important because that increases the likelihood that a grain will be found in sediment (specifically, anoxic ones such as lake, ocean, and icecap sediments). An abundance of pollen is a contributing factor as to why it is considered to be the most numerous fossil (Lipps 2013; Frederiksen 2013). While an abundance of pollen certainly makes it easier for a researcher to extract information, a lack of pollen can be useful as well. Many variables, including soil phosphorous levels, can influence pollen production and pollen grain size; as technology and techniques improve, it is possible that more information about the past can be extracted from pollen counts (Stephenson 1993).

Knowing the limiting factors, or requirements for plant life, can provide valuable information about the environment at the time of pollen deposition. One such limiting factor is sunlight; some plants, like *Acer rubrum* (Red Maple), do not provide a researcher with much data as they are sciophytes, but also quite tolerant of large quantities of sunlight. Heliophytic plants, on the other hand, tend to be slightly more telling about environmental phenomena that shape a region. It may be a concern that deposits in downstream locations from northward-originated pollen would interfere with the sample, because of pollen's mobility in water. Chmura and Liu (1990) conducted a study to allay this concern; their conclusion was that pollen that originated upstream did make its way into downstream samples, but the numbers were incredibly diluted and did not interfere with analysis. Chmura and Liu (1990) also concluded that the pollen assemblage represented the entire Mississippi River drainage system.

1.4 Use of Pollen and Spores in Paleotempestology

A uniformitarian approach is taken for both paleoenvironmental reconstruction and paleotempestology. This means that it is assumed that the geographic location of the backbarrier environments from which cores are collected have not changed drastically from their prehistoric locations. It is also assumed that climactic events and the Earth function much the same in the past as it does now (Liu 2004b).

Paleotempestology is a relatively new field of science that employs geological proxy techniques including overwash sand layers, diatoms, foraminifera, pollen, and phytoliths collected from coastal lakes and marshes to study past hurricane activities (Liu 2004b); it involves locating possible sites of ancient tempests and analyzing cores to determine whether or not a major cyclonic event has occurred (Liu 2004b). The entire field is based upon the knowledge that over-wash fans are generated after hurricanes (USGS 2013). The science of paleotempestology utilizes a variety of paleosols, paleontological, and paleoecological principles to determine if and when a cyclonic event has occurred.

Pollen can be useful for paleotempestology in several ways. Often, pollen is used as a means of relative age dating. Again, using the principle of fossil succession and the law of superposition, researchers are able to determine a rough time period through use of pollen from plants like Ambrosia and Rumex; population booms in these sun-loving plants tend to follow disturbances, especially the clear-cutting of massive swaths of land following the arrival and settlement of Europeans in North America (Liu 2004b).

Pollen grains in the paleoenvironmental record can also be used as possible indicators of paleohurricane occurrences. Lakes that are inundated after a tempest event are often filled with saltwater; the influx of seawater creates a favorable environment for salt-tolerant vegetation. The presence of pollen from a water-dwelling and salt-loving plant in a freshwater lake would suggest that the lake suffered an intrusion of saltwater potentially by a tempest event if the salinity persisted, especially if corroborated with other data (Liu 2004b). Pollen, like fine sediment, should deposit in the highest concentrations where energy levels are low; aluminum, potassium, and silica also vary with respect to one another in reservoirs (Lopez et al 2006; Liu 2004b).

1.5 Data Collection

The process of collecting pollen data begins with the decision of where to take a sample. If data for paleotempestology is desired, then the requirements slightly alter. Generally, when looking for a desirable location for samples, an overwash fan is needed (Liu 2004b). An overwash fan is formed when intense waves break the crest of a dune, causing sand to be deposited inland. It would then, be of poor choice to look for evidence of hurricanes in areas that are not near a beach. The most useful location to a paleotempestologist would be an enclosed lake, that is freshwater, that is not too far inland and has a sand dune separating it from the beach; all of these factors are important because: lagoon lakes may lose overwash fans through tides, freshwater would have marked changes in salinity, lakes without a sand dune would lack sediment to record the tempest event with, locations too far from the ocean will also lack sediment, and those are too close to the sediment may be inundated with saltwater without a major event occurring (Liu 2004b). Once a lake or back-barrier marsh location is selected, a rod can be used to probe the location; the grating sound of the rod indicates inter-bedding of organic material and sand; the depth at which this grating continues to occur indicates how far back the record is likely to go (Webb and Donnelly, 2004). However, when attempting to conduct paleoenvironmental reconstruction, anoxic environments are preferred because oxidation is one of the only processes known to destroy a pollen fossil (Faegri and Iverson 1964).

Coring is the first step for receiving anything other than surface pollen. When examining cores, the law of superposition is utilized. The cardinal assumption is that the youngest layers are atop the soil column and the oldest layers on the bottom of the column. This is a particularly safe assumption since sediment cores tend to be taken from unconsolidated Quaternary beaches, lakes, and icecaps that do not receive much tectonic activity, and generally do not have overturned layers (Fagan 2013). The method taken for coring depends upon current environment at the site; there are several methods for coring, but two are the most useful for Quaternary data.

For this study, a modified Livingstone (piston) corer was used to retrieve sediment from a marsh environment. In this simple coring method, a 1.5 m long, clear PVC pipe is pressed into the ground as far as possible, stabilized and forced downward by several operators as seen in figure 1.2 below. To re-trieve the sediment, the operators simply pull the core out of the ground and seal it on both ends to be transported back to the lab for analysis.

Figure 1.2 Coring using a Modified Livingstone Core on Bay Jimmy, LA in April 2011

1.6 Previous Works

Liu and Chmura (1990) performed extensive work in the Mississippi River delta to prove that pollen is a reliable proxy for the area. The concern was that because the delta acts as a base level and repository for pollen, that upstream locations may be overrepresented in the data. Using modern sediments, Liu and Chmura (1990) were able to show that northern taxa were represented in low concentrations and did not impede analysis.

Aliotta et al (2013) utilized marine fauna to map sea levels in the South Atlantic during the late Quaternary. The study concluded that sea level was lower globally during this time and that rivers had an extended base level that allowed deltas to prograde until the last glacial maximum ended; upon the end of the last glacial maximum, the deltas began to retrograde.

Kidder et al (2008) used archaeological data to track large-scale climatic and showed that landscapes around the Mississippi River remained stable during the last 2,000 years. Unfortunately, Kidder et al (2008) did not address the landscape of deltaic communities in Louisiana and Mississippi. Delcourt and Delcourt (1996) showed a stable humid and warm environment in the lower Mississippi River Valley over the last 4,000 years. Like the Kidder et al (2008) study, the study by Delcourt and Delcourt (1996) only addressed regions north of the delta. Both studies are inadequate for addressing how coastal floral communities have been affected by climate change. Bay Jimmy's proximity to the sea causes the environment to be more responsive to sea level changes than the locations of the previously mentioned studies.

The sea level in the Gulf of Mexico has been slowly rising over the course of the Holocene as seen in figure 1.3 below (Otvos 2004). Another study by Anderson et al (2013) corroborates this account, showing a .4-.6mm increase in sea level rise every year since ca. 4000 Yr BP. If there was no progradation in Bay Jimmy during this time period due to an increase in sediment supply, then, it should be expected that the marsh will slowly retreat.

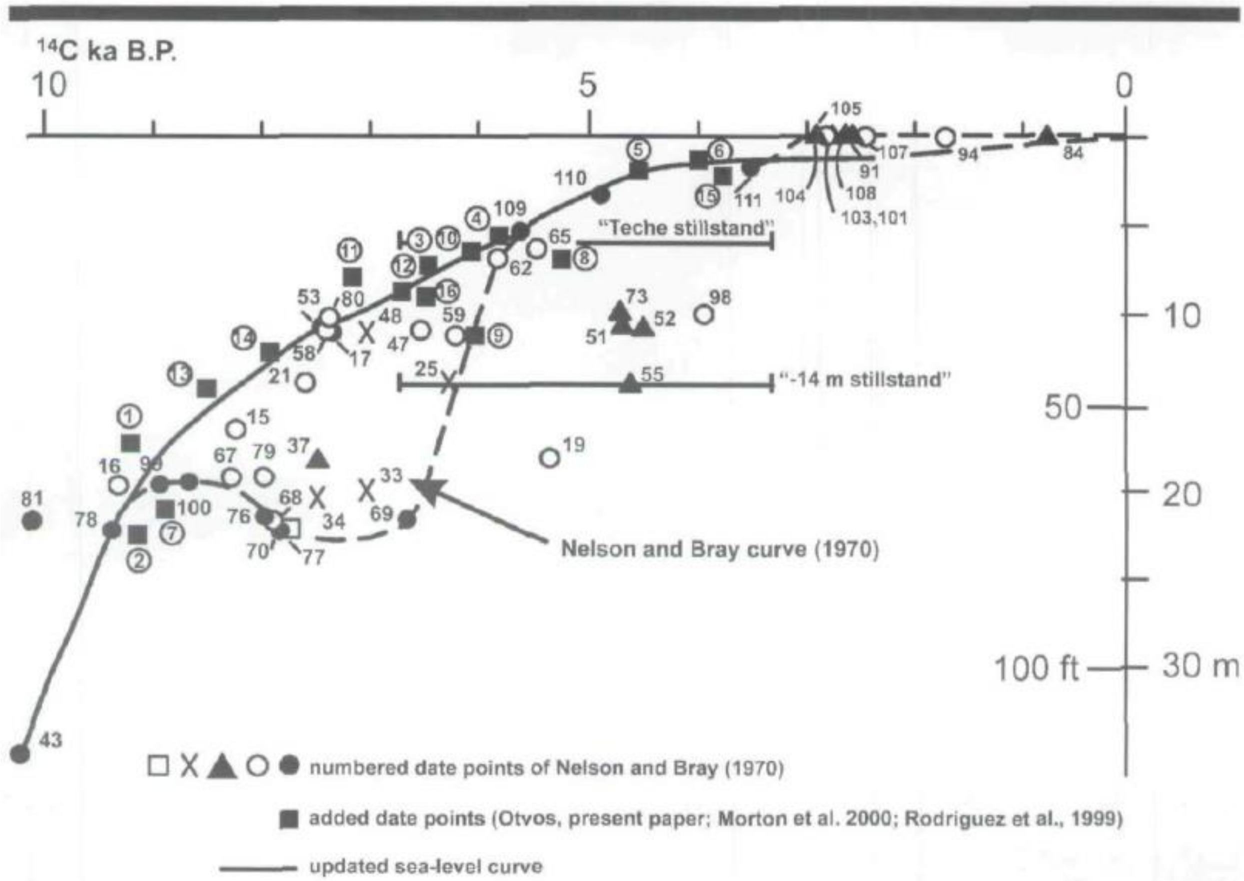

Figure 1.3 Sea Level Curve for the Gulf of Mexico in the Holocene (Otvos 2004)

Marshes on the Louisiana coast are deteriorating at an alarming rate due to rising sea level and regular saltwater inundation. Saltwater submergence slows peat accumulation, which a marsh depends on to grow; this loss of growth makes it easier for the marsh to become submerged in the future, leading to rapid degeneration over time (DeLaune et al 1994). The USGS National Wetlands Research Center estimates that the state has lost approximately 1900 square miles of coastal land since 1932, an area about the size of the state of Delaware, or acreage equivalent to 80 Manhattans (Kiage et al 2005). Normally, marshes retreat inland in response to these changes, but anthropogenic barriers are preventing this sort of natural remediation (Couvillion and Beck 2013). This combination of sea level and anthropogenic modification has caused Louisiana to lose more of its coastal wetlands than all other states in the US combined (Glick et al 2013). Glick et al. (2013) predict that even given conservative estimates of rising sea level, Louisiana will lose from 42-99% of its marshes by 2100. In addition to these factors, storm activity has the potential to accelerate this loss by rapidly inundating marshes with water up to 200cm high, as in Hurricane Lili (2002), which can introduce too much salinity, scour vegetation and soil, and convert marsh to open water (Barras et al 2004; Kiage et al 2005; Morton and Barras 2011). Barras et al (2004) predict that between year 2000 and 2050, 674 square miles of land will be lost and that 161 square miles will be recovered due to government projects. These predictions, however, contain a 25% margin of error that is affected by possible changes of marsh behavior in relation to climate change.

A study closer to the coastline was conducted by Reese and Liu (2001). It concluded that the floral community had not responded to hydrology in the Mississippi River delta; unfortunately, the research area of Bluff Swamp, Louisiana is an inland Cupressaceae swamp and does not resemble the salt marshes that border the exterior coastline. Taking a second look at the region, alongside X-Ray Fluorescence (XRF) and Loss on Ignition (LOI) would help to develop a better theory for what the floral community has responded to.

1.7 Research Questions and Objectives

The goal of research in the Bay Jimmy core is to answer the question: How has the environment of Bay Jimmy, Louisiana changed during the last 1,200 years? This encompasses questioning whether or not major tempest events and floods have taken place in the site's history. Mapping the evolution of Bay Jimmy's landscape would assist government agencies development of risk assessments for Louisiana's coastline. With rising sea level, and no increase in sediment supply, marsh naturally retreats inland, but anthropogenic barriers may prevent such retreat, leading to their decline and eventual destruction (Couvillion and Beck 2013; Glick et al. 2013). This response to relative sea level will need to be taken into consideration regarding future policy.

2 STUDY AREA

Figure 2.1 A Google Earth Image of Bay Jimmy Louisiana Showing the Location of Core BJ4 (29°27’26.4”N 89°53’15.14”W)

Figure 2.2 Onsite Photo of Bay Jimmy

Bay Jimmy, above in Figure 2.1 and 2.2, is made of small islets that exist off of the Mississippi River (29°26’ N, 89°52’ W). It was formed from the deltaic system of the Mississippi that exists in Louisiana. The small embayment, which exists inside of the larger Barataria Bay, consists largely of marshes today (shown in Figure 2.2). These marshes are able to keep their largely mud consistency because of their proximity to barrier islands and the Mississippi River Delta itself. Bay Jimmy exists on the outer edge marsh and channel system surrounding the river and thus has seen most of the larger sediment deposit out before reaching its location. Large quantities of sand are kept out of the bay by the ten mile tidal delta and threshold system created behind and by the barrier islands as seen in figure 2.3 below (Bird 2008).

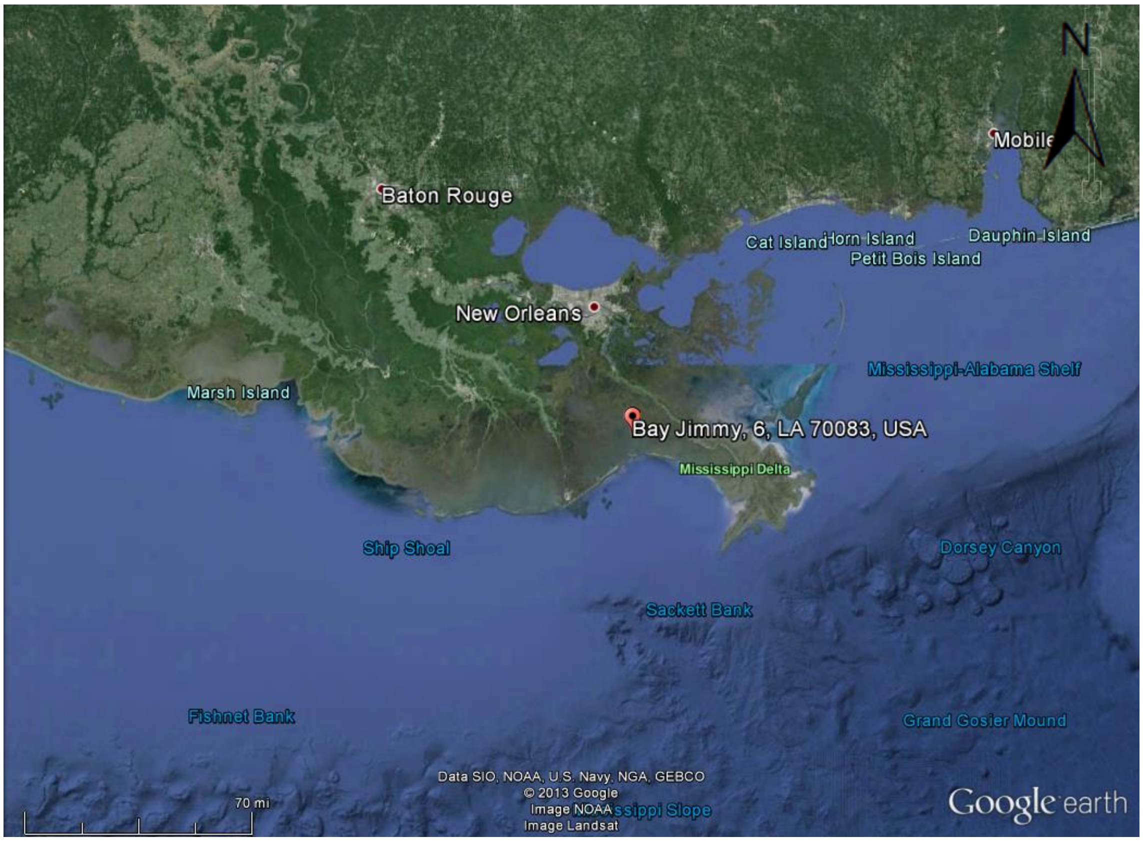

Figure 2.3 A GoogleEarth image of Louisiana coastline in the northern Gulf of Mexico showing Bay Jimmy in the context of the greater Louisiana area

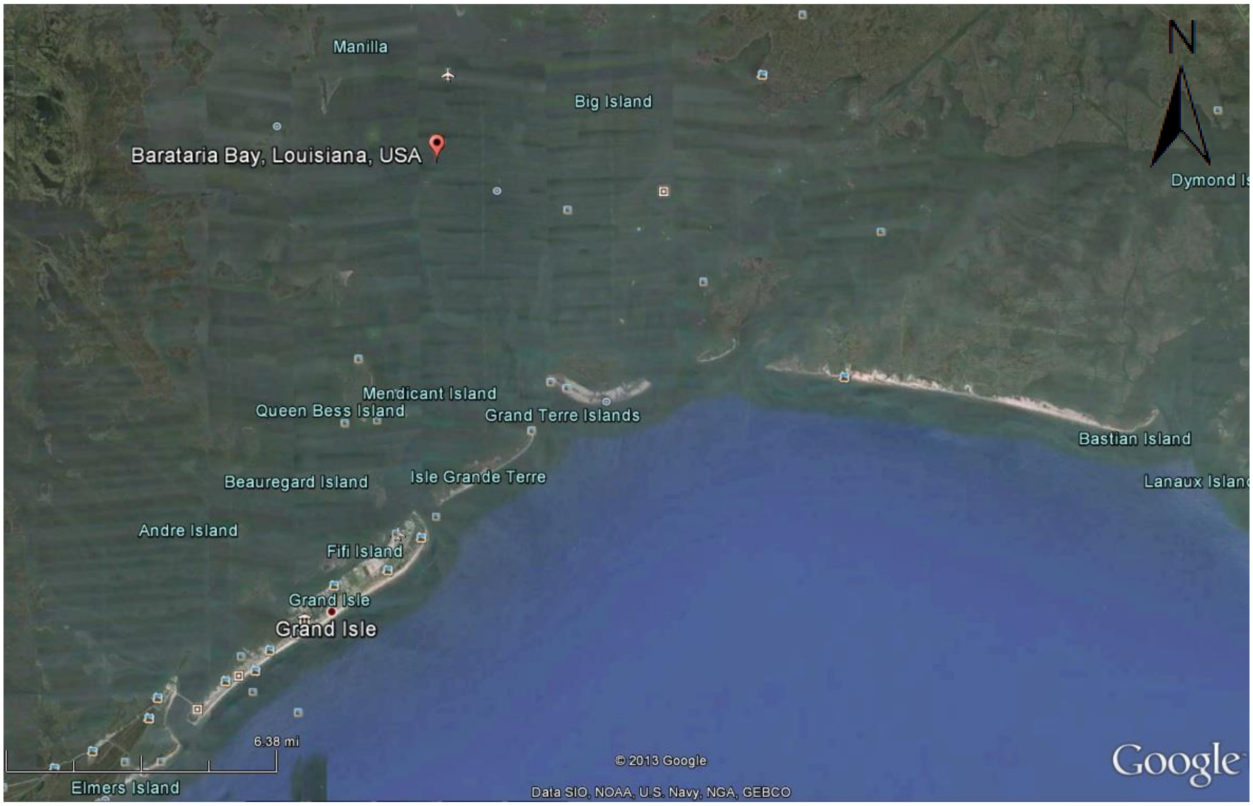

Figure 2.4 A GoogleEarth image showing Barataria Bay and its barrier islands

Marshes are ideal for cores for examining pollen because, as previously stated, pollen requires reducing environments in order to be preserved. The anoxic environment that muds created from the Mississippi River, are then ideal for pollen data collection in the reconstruction of paleoenvironments. LOI can be used detecting the presence of paleotempest events as well. As previously stated, a section of the core containing low organics and water, with an increased presence of carbonates, would point to the occurrence of such an event. Hurricane trajectories from the Atlantic basin hurricane database (HURDAT), as seen in Figure 2.5, show hurricanes affecting the Mississippi River Delta, especially in recent years. Recent studies have indicated that southeastern Louisiana is particularly affected by flooding due to tempest activity and low relief; rapid flooding of 200cm has been documented along deltas, such as the Atchafalaya, which have been shown to uplift vegetation and soil from the marsh (Barras et al 2004; Kiage et al 2005).

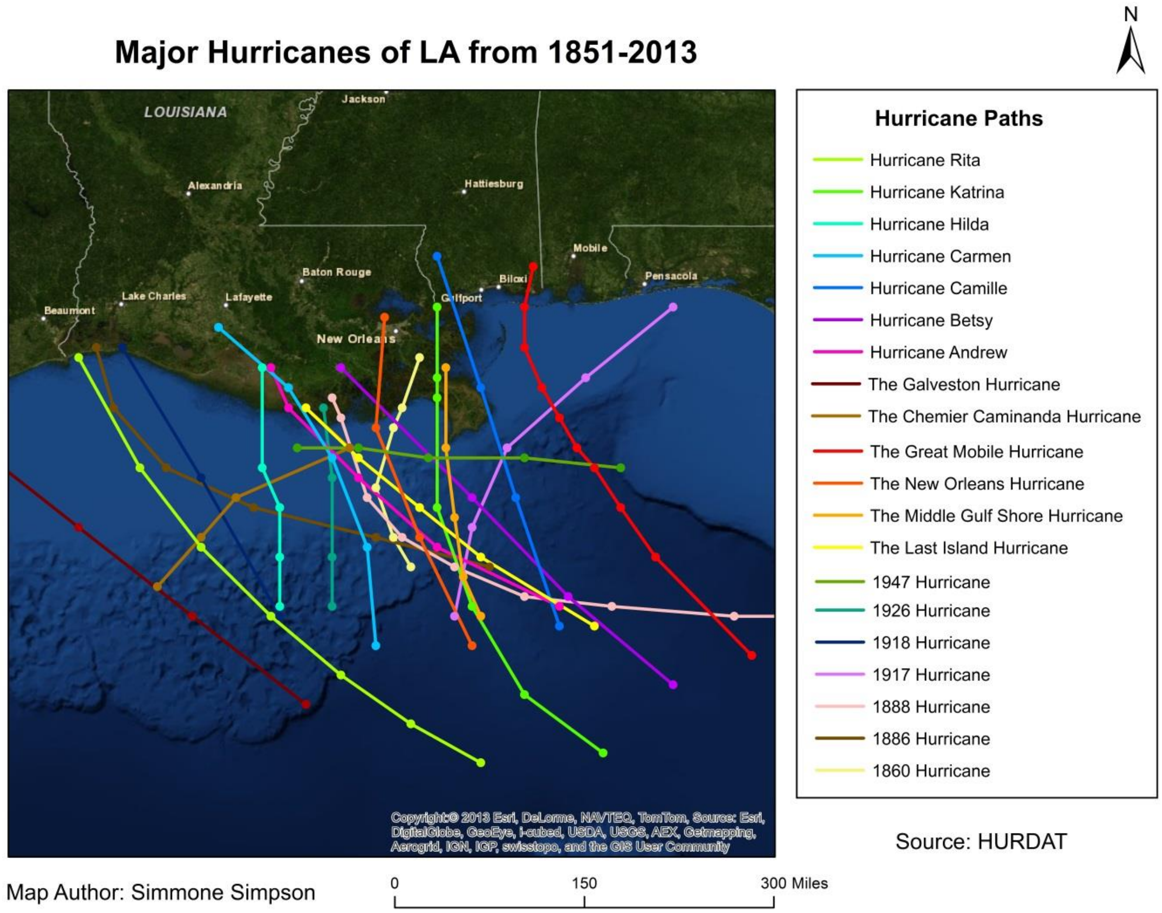

Figure 2.5 A Map of Hurricane Activity along the Louisiana Coast since 1851

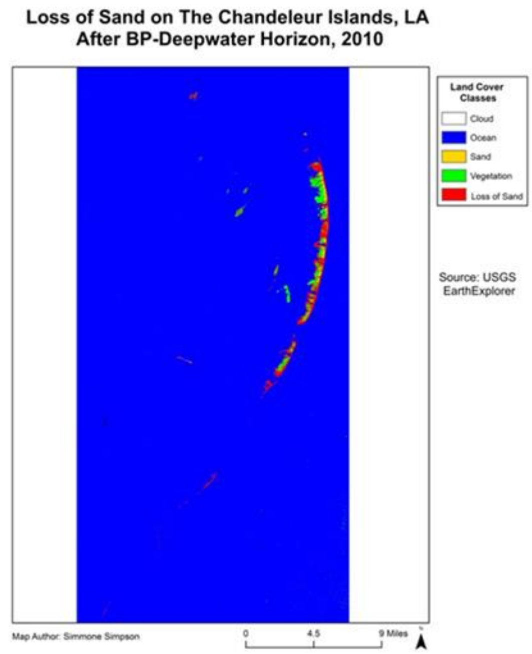

Figure 2.6 A Change Detection Map Depicting Loss of Sand After the Deepwater Oil Spill on the Chandeleur Islands

Data from Bay Jimmy has become all the more valuable since the Deepwater Horizon Oil Spill. Barataria Bay received a large portion of the oil that inundated Louisiana's coast. Estimates from research conducted in 2010 estimated that Bay Jimmy alone absorbed 32,000 gallons of oil (Jervis 2010). As of 2012, the National Wildlife Federation found crusts of asphaltene (a thick hydrocarbon) atop the Cordgrass marshes of Bay Jimmy (Schleifstein 2012). The same report found oil bubbling from the soil and birds with oil-slicked wings. This oil poses a danger to the preservation of sedimentary data because it causes the erosion of coasts and islands (Biber et al 2012); this is because the oil kills the roots of the plant life that keeps soil and sediment in place. A map showing the loss of island area is shown in Figure 2.6. Biber et al (2012) states that the effects may not be permanent, but do seem to point to significant damage in Bay Jimmy because its Cordgrass marshes are more sensitive to the effects of an oil spill. Using remote sensing data, I have generated maps that suggest that oil deposition leads to erosion. Subsequent rebound of salt marshes is attributed to the ability of rhizomes to survive beneath oil and Asphaltene mats (Lin and Mendelssohn 2011).

3 METHODS

The Bay Jimmy cores used for this study were collected by Dr. Larry Kiage and Dr. Deocampo, GSU, in the spring of 2011. The sediment was collected using a modified Livingstone corer that was able to retrieve 195cm of sediment. The cores were subjected to loss on ignition analysis (LOI) following the techniques described by Williams (2013) and Kiage et al (2011). The LOI analysis consisted of taking a cubic centimeter of soil for every centimeter of core. The technique utilizes the changes of mass after cooking the sample at various temperatures. The samples are weighed before and after being heated to 105˚C overnight, 550˚C for an hour, and lastly 1,000˚C for an hour. The change in weight reflects the amount water, organics, and carbonates in the original sample, respectively. XRF data was generated using a handheld Innov X-Alpha 4000 Energy Dispersive X Ray Fluorescence Spectrometer using approximately 30 second intervals during the Fall of 2013.

The samples for establishing the chronology of the core were processed by Beta Analytic Inc. Laboratory in Miami, Florida. The lab performed Accelerator Mass Spectrometry (AMS) radiocarbon-14 dating to establish the chronology of the core. The samples for dating were taken with a clean metal spatula that was cleaned in between each sample. A mixture of plant and soil material was taken in order to give the lab enough material to obtain an age. The dates were within +/-30 years of the ages reported.

3.1 Pollen Analysis

Once the core and other data are extracted, there are several more steps that are taken in order to make it possible for pollen to be readily viewed and counted under the microscope. The first step is rather rudimentary; it involves scooping out a portion of sediment that is roughly one cubic centimeter. Next, a Lycopodium spike is added to the 15ml tubes; this is used to aid in final counting, as a representative sample would be counted to 1000 spores or 300 pollen grains (Colinvaux et al 1999).

KOH (Potassium Hydroxide) was used to rid the sample of organic material. The tubes were filled with 10 % KOH and stirred while sitting in a water bath for roughly 20 minutes. In organic-rich samples (which tend to occur in paleotempestology due to the samples of anoxic marshes) the process was repeated several times before the liquid appeared to be clear, and thus free of most organic material that can make counting difficult. After the final cooking with KOH, the sample was centrifuged one last time (suggested to be for three minutes at 3500 rpm) and decanted to get rid of extra material; centrifuging works extremely well with pollen because it is much denser than water and readily separates out of the column (Colinvaux et al 1999).

The next step is to remove the sample of carbonates; 10% HCl (Hydrochloric Acid) was added to the 15ml tubes. This is an extremely reactive process and it is best to add small amounts of HCl at a time and gently stir while the sediment sits in a boiling water bath. Again, the samples were centrifuged and decanted. This process was followed by a 48% HF (Hydrofluoric Acid) bath. HF is used to rid the sample of silicates like sand and clay that were not sieved out of the sample (Colinvaux et al 1999). It is important to note that teflon tubes and wooden stirring sticks are important for this step, as HF will dissolve glass. These samples were cooked in a water bath and stirred for 20 minutes. Ethanol was added to the bath to cool them down before they were centrifuged and decanted; a sample slide was made to test for grit, if present, then the HF procedure was repeated (Cushing 1977). Directly after completing the HF, it is important to directly proceed to another HCl rinse; this helps to break up clumps formed during the HF cycle and leaves a surface safe to perform the acetolysis solution on (Colinvaux et al 1999).

The acetolysis solution was made up of 45ml of acetic anhydride and 5ml of sulfuric acid. This process helps to polish the sample by removing the remaining organic material from the sample itself and the surfaces of the pollen grains; the process also serves to lightly stain the pollen to make it more readily visible under microscope (Cushing 1977). This process, unlike the others, is much more precise and short; the water bath must be at a rolling boil and must last for exactly two minutes. Once centrifuged and decanted it is important to add Glacial Acetic Acid as a rinse (not water, as it will react with the acetolysis solution); the sample was then centrifuged and decanted and transferred to small vials, where it was be dyed or simply let out to dry. Once the solution was dry the remaining sediment was suspended in silicon oil.

Mounting the slides was the final step to pollen processing. It is important to handle the remaining sediment delicately, as pollen can break or split if handled vigorously. From here, a collection of pollen keys were used to identify individual grains; once the required numbers of grains were counted per sample (300), the data was compiled for graphical analysis.

Finally, the LOI and pollen data were entered in a spreadsheet and graphed using Tilia 1.7.16 in order to interpret changes in environmental-facies and possible tempest layers. The data was then graphed with a litholog to show the stratigraphic changes through time. Plant characteristics were obtained through the U.S. Department of Agriculture (USDA) website. These characteristics were used to infer paleoenvironments. For pollen identification the works of Willard et al (2004) and Demske et al (2013) were utilized.

4 RESULTS

4.1 Chronology

Table 4.1 Chronology for Core BJ4

Total Core Depth(cm)	Material Sampled	Beta Codes	2-δ range cal. Yr AD	Year BP	AD
20	Peat	355731	N/A	108+/-.3 pMC	Modern
75	Peat	355732	1450-1640	360 +/-30	1545
110	Peat	355733	1290-1410	600+/-30	1350
150	Charred Material	355734	1020-1160	950+/-30	1090
180	Peat	355735	720-740; 770-890	1200+/-30	750

Table 4.1 lists the ages associated with the total depth of the core. All of the samples were AMS radiocarbon dated and processed by Beta Analytic Inc. Laboratory, Miami, Florida. Samples were taken at core depths of 20cm, 75cm, 110cm, 150cm, and 180cm. They have respective dates of 108, 360, 600, 950, and 1200 years BP (before present), with a margin of error of +/- 30 years. The first three dates of 108, 360 and 600 B.P. were taken where significant environmental changes were suspected to occur. The dates acquired from Beta Analytic were likely accurate and fell into good chronological order due to the fact that the coring location was in a relatively calm bay. Below are pictures of the types of material used for AMS C-14 Dating at the given depths.

Pictures of Samples that were subjected to AMS C-14 Dating

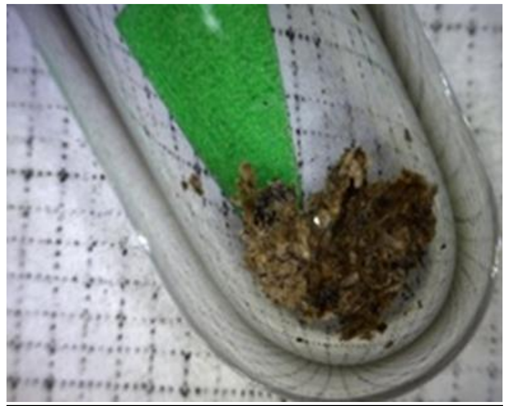

Figure 4.1 2.6 mg of peat material at 20 cm analyzed (scale 1 mm x 1 mm)

Figure 4.2 2.2 mg peat material at 75 cm analyzed (scale 1 mm x 1 mm)

Figure 4.3 .9 mg peat material at 110 cm analyzed (scale 1 mm x 1 mm)

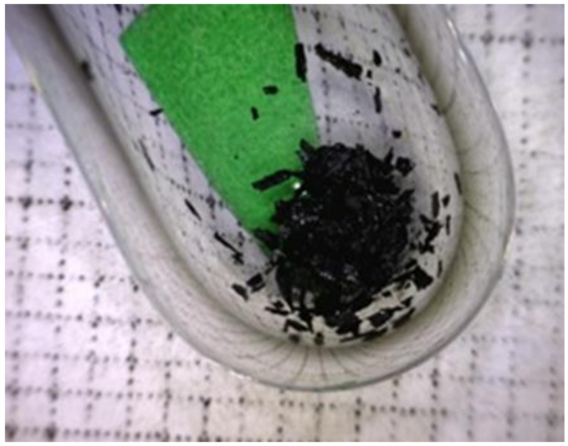

Figure 4.4 2.6 mg of charred material at 150 cm analyzed (scale 1 mm x 1mm)

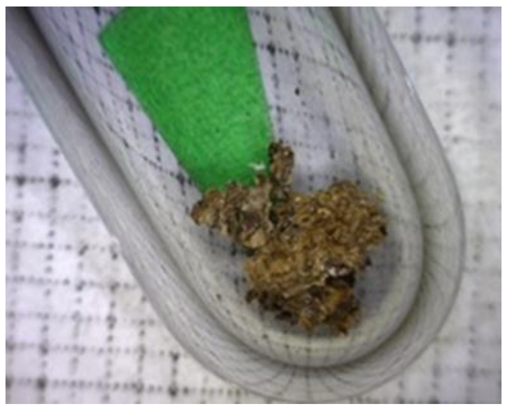

Figure 4.5 3.6 mg of peat material at 180 cm analyzed (scale 1 mm x 1mm)

4.2 Pollen

Figure 4.6, below, shows percentages of dominant taxa and loss-on-ignition through time in core BJ4. Chenopodiaceae and Amaranthaceae are grouped together and collectively called Cheno-Am (Figure 4.15) for the purpose of this study; phylogenetic studies have determined that Chenopodiaceae and Amaranthaceae are similar, although it is the practice of some researchers and government agencies to study them separately (Burrows and Tyrl 2012).

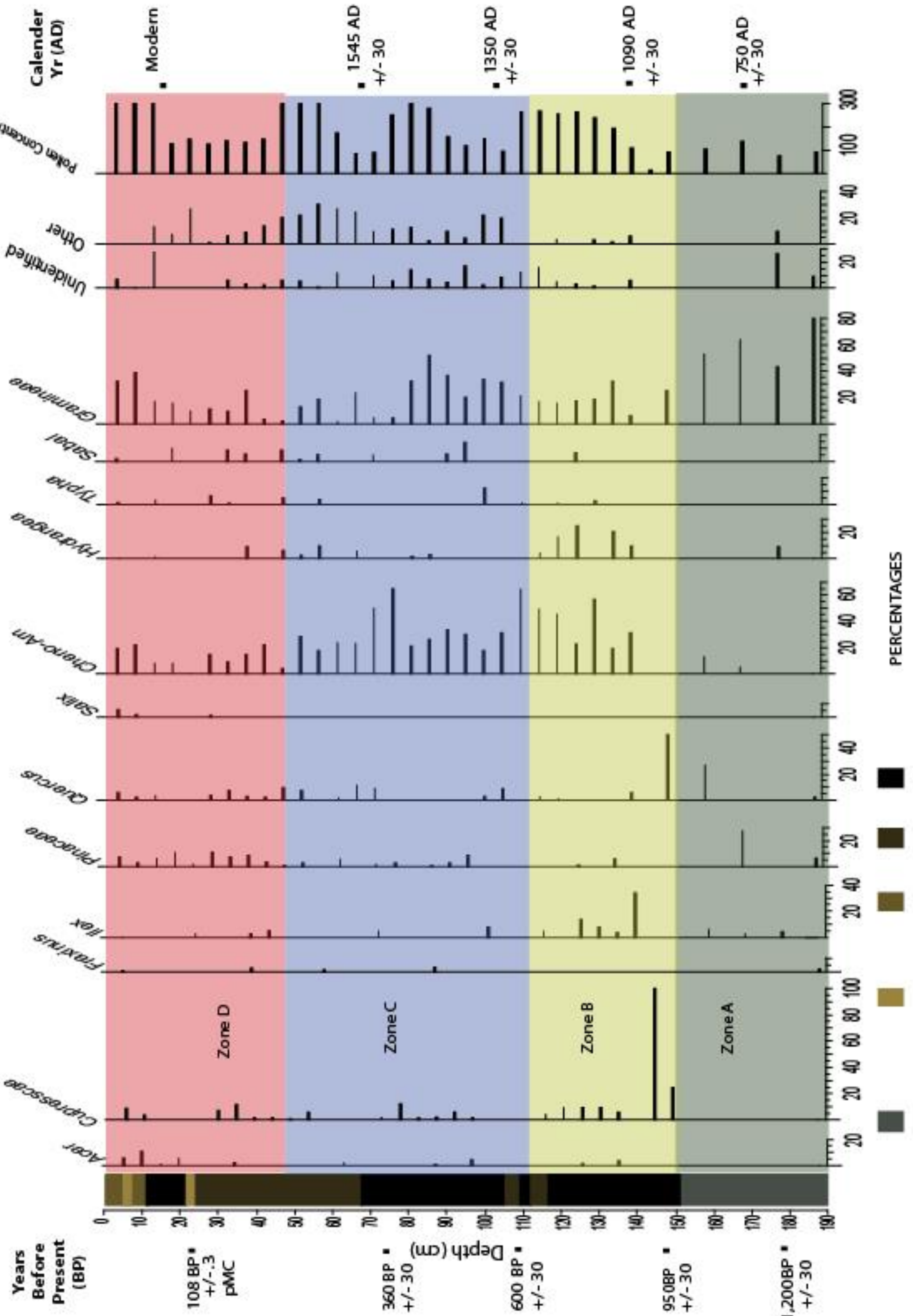

Figure 4.6 Percentages of Pollen at Depth on Bay Jimmy Core BJ4

According to the Missouri Botanical Gardens (2013), Chenopodiaceae and Amaranthaceae both contain several species that are salt tolerant and both families prefer disturbed environments. These two families also contain pollen grains that are similar in appearance, making it difficult to distinguish between the two (Sklar and Van Der Valk 2002). Heliophytes, like Gramineae (grass), and the Cheno-Ams, waver between highs and lows, but are generally present in appreciable numbers when combined (Figure 4.13).

From ca. 1,200-950 Yr BP (190cm to 150cm) grasses dominate the landscape and *Quercus* (Figure 4.14) gradually increases. This leads into a community that is dominated by *Hydrangea, Ilex*, and Cupressaceae, all of which are at least moderately shade-tolerant. At a depth of 145cm the data is skewed as most of the sample was lost during centrifuge; this causes there to be an overrepresentation of Cupressaceae since very few grains were left to be seen and they just happened to be Cupressaceae. At ca. 950 Yr BP (150cm), some charred material was found; at the same depth *Quercus* increases and Cheno-Ams are not present. From ca. 950-600 Yr BP (150cm-110cm) heliophytic grasses and Cheno-Ams become dominant. Cupressaceae and *Ilex* continue to be well represented. *Typha* (Figure 4.9 and 4.10), a genus adapted to wet conditions first begins to appear. From ca. 600-220 Yr BP (110cm to 45cm) heliophytes complete a max cycle. *Quercus* begins to increase with the decline of Cheno-Ams at ca. 360 Yr BP (70cm). Lastly, from ca. 220 Yr BP (45cm) until the top of the core, grasses, Pinaceae, and Cheno-Am's start to recover their percentages. Their increase coincides with the large losses of water and organics and an increase in terrestrial sediments; *Typha* is also represented at higher rates than the rest of the core through this time.

Throughout the core a trend takes place. Shade-tolerant vegetation like *Quercus,* and Cupressaceae, recuperate shortly after Pine forests are established. Once the heliophytes have dominated the environment, *Quercus* and Cupressaceae soon follow; these are then followed by *Ilex*, which is tolerant of wet conditions, then *Acer*, which is better suited for non-saline swamplands. Hydrangea is a non-arboreal genus that also flourishes in the shade and peaks once forestry is established.

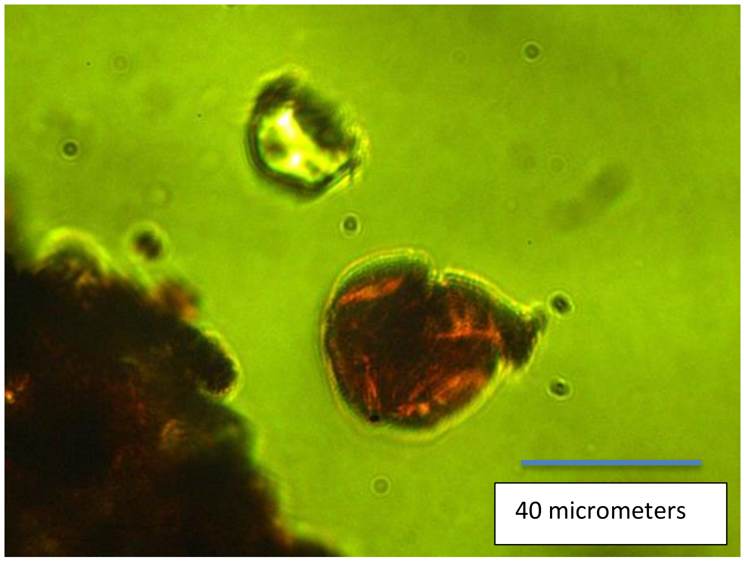

Figure 4.7 *Typha* (1000x)

Figure 4.8 *Typha* (1000x)

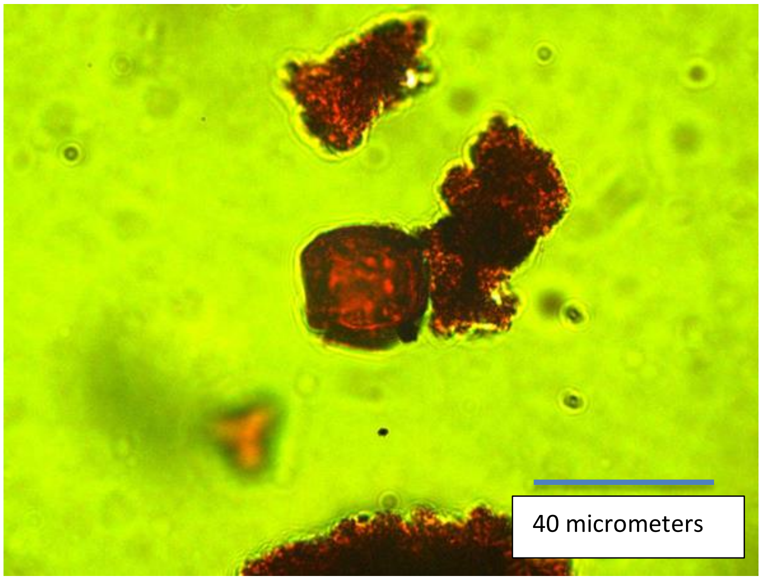

Figure 4.9 *Fraxinus* (1000x)

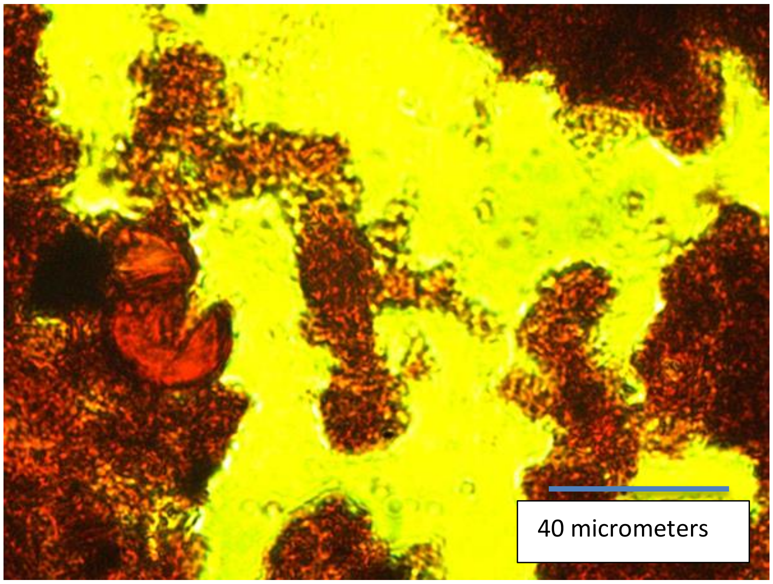

Figure 4.10 Cupressaceae - slit grain (1000x)

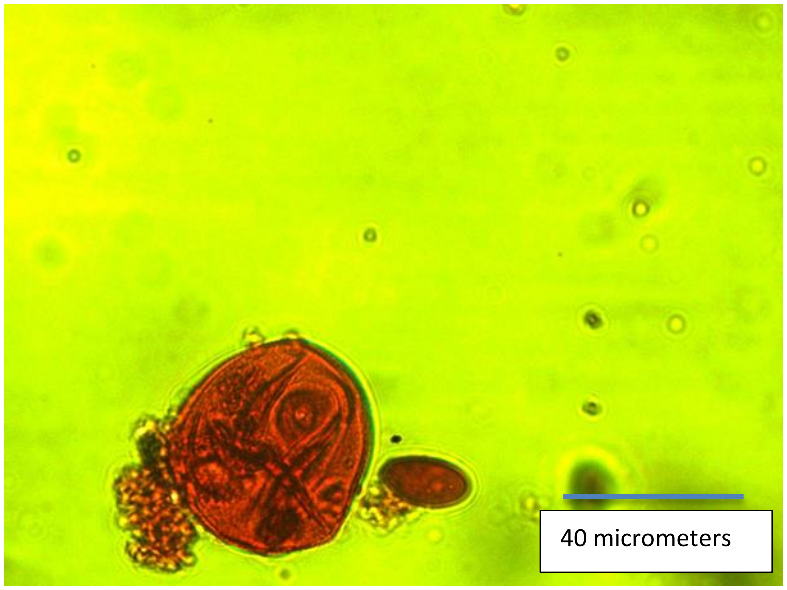

Figure 4.11 Graminae - on left (1000x)

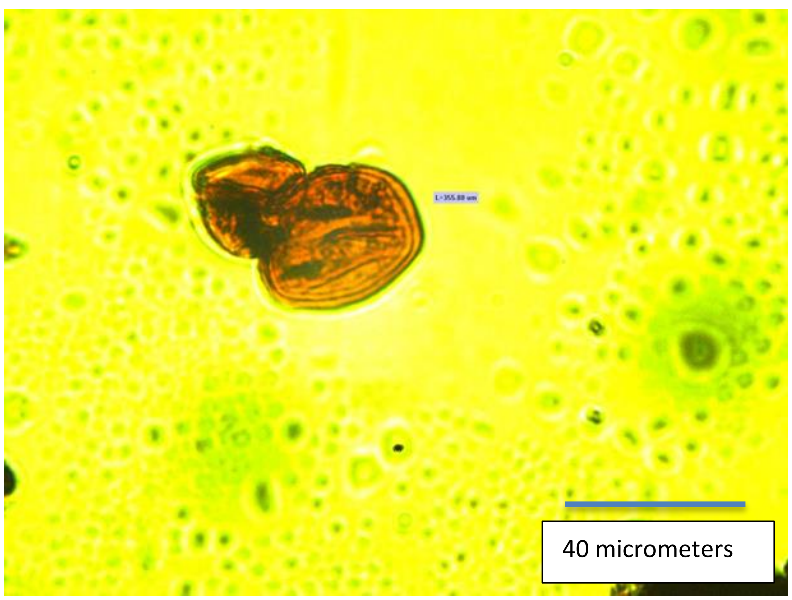

Figure 4.12 *Quercus* - on right (1000x)

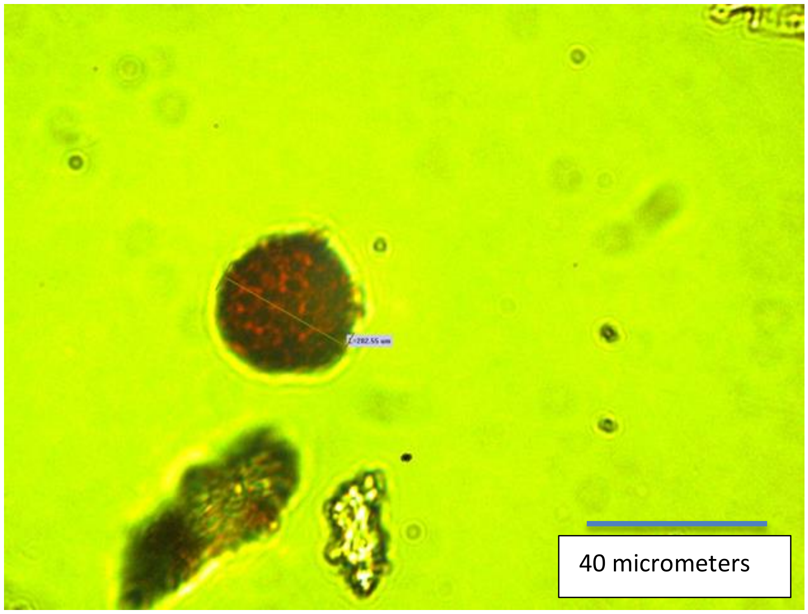

Figure 4.13 Cheno-Am (1000x)

4.3 LOI and XRF

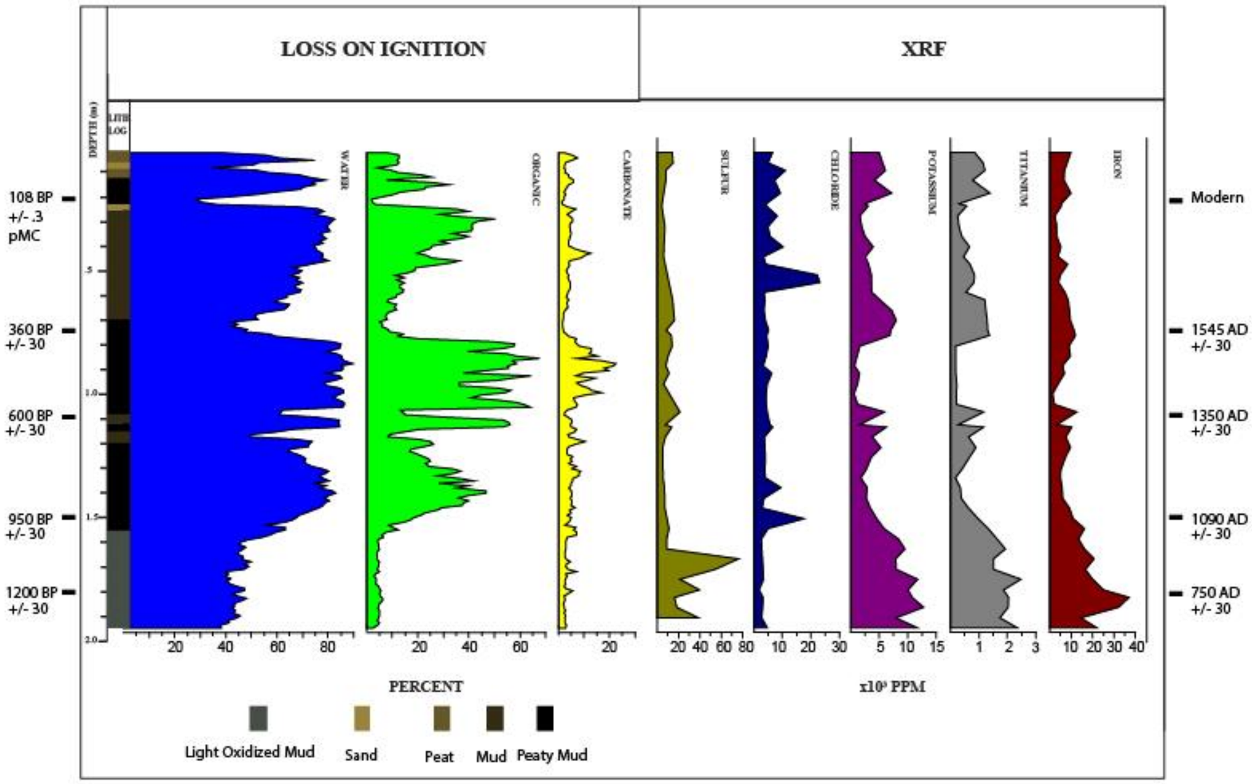

Figure 4.14 LOI and XRF Data, at Depth, for Bay Jimmy, Louisiana Core BJ4

Figure 4.14 shows the results of LOI i.e., the percentages of water, organic content, and carbonate contents through time; the figure also shows concentrations of dominant elements in the core. The XRF data suggests that depths between 190-150cm (ca. 1,200-950 Yr BP) are consistent with a terrestrially influenced environment as evidenced in the high proportions of titanium and potassium. The mud is oxidized and red due to high iron concentrations, also evident in the XRF data. This portion of the core appears to have much less mud than the rest, as exemplified by the lack of water and organics.

High proportions of water, and chlorine begin at the depth of 150cm (ca. 950 Yr BP) and continue through 110cm (ca. 600Yr BP). This environment is, however, punctuated with two events that are marked by an extreme drop in water from about 80-25% for the first event and 80-40% for the second, and organics from about 40-0% for event one and 30-5% for event two, as well as a large increase in titanium, potassium, and sometimes chlorine and sulfur**.** The two sand layers of the core were also present in this region around 25 cm (ca. ~108 Yr BP) and 8 cm (2005 AD)

From the depth of 110cm to 45cm (ca. 600-220 Yr BP), terrestrial elements reach their lowest throughout the core. Chlorine and sulfur remain high and carbonate material reaches its highest point. From 220BP until the present shows an increasing proportion of terrestrial elements.

5 DISCUSSION

Over the course of the past 1,200 years B.P., Bay Jimmy, Louisiana has had a relatively stable climate, but has been shaped by major events. These instances have helped to create a monoculture of warm-temperate and hydrophilic plants. XRF, LOI, and pollen succession were used to categorize these events. Core BJ4 is used as sample representative the Bay Jimmy environment.

Table 5.1 provides a listing of the salt, shade, and fire tolerance of the plants whose pollen was used in this study (Table 5.1). While pollen may be an excellent indicator of paleoenvironments, it can potentially be transported in from surrounding locations, and thus would be representative of a larger scale environment (Chmura and Liu 1990). For this reason it is useful to examine other proxy datasets for environmental interpretation, including XRF data; therefore a list of interpretations using XRF data is shown below (Table 5.2). LOI was also utilized, along with the physical examination of the core itself. In the discussion that follows, the paleoenvironments are interpreted in view of the zones shown in Figure 4.6 above.

Table 5.1 The Salt, Shade, and Fire Tolerance of the Plants as Reported by the USDA

Genera/Family	**Salt-Tolerance**	**Shade Tolerance**	**Fire Tolerance**
Acer	none-medium	intermediate-tolerant	none-low
Cheno-Am	high	intolerant	low
Cupressaceae	low-high	intermediate	none-low
Fraxinus	none-medium	intolerant-tolerant	none-high
Gramineae	low-medium	intolerant	low-medium
Ilex	none-medium	intolerant-tolerant	none-high
Pinaceae	none	intolerant-tolerant	none-high
Quercus	none-medium	intolerant-tolerant	low-high
Sabal	none-medium	tolerant	low-medium
Salix	none-medium	intolerant-tolerant	low-high
Typha	low-medium	intolerant-intermediate	high

Table 5.2 T General Implications of Different Elements Recorded by the XRF Analysis

Element	**Interpretation**
Chlorine	Usually indicates the presence of salt water.
Iron	Usually present in terrestrial sediments. Can indicate pyritization if accompanied by sulfur (Meyer 2013).
Potassium	Usually present in terrestrial sediments (Meyer 2013).
Sulfur	Usually indicates the presence of salt water. Can indicate pyritization if accompanied by sulfer (Meyer 2013)
Titatium	Usually present in terrestrial sediments. Large spikes may indicate land clearance (Woodruff 2008).

5.1 Zone A: 1,200-950BP (190-150cm)

Zone A is interpreted to reflect a time period when this region was a marsh that received a significant amount of depositional input from the land behind it. This is evidenced by the presence of sand amidst the visible oxidized mud layer as detected by the LOI, and the accompanying spikes in the terrestrial elements of iron, potassium, and titanium. An increase in sulfur and iron may indicate the pyritization of the marsh in an anoxic environment until around ca. 950 Yr BP (150 cm). After this time, an increase in Cupressaceae and *Quercus* at the end of zone A, accompanying the decline of more heliophytic plants, may represent a transition into a more arboreal environment. In addition, a generally low level of plant material, and a decline in iron and sulfur may indicate a transition to a less anoxic environment.

For this region of the core, the LOI analysis unveiled lower quantities of water and organics, which are generally associated with environments possessing high sand content. Despite the fact that this area appears to be largely composed of oxidized mud, the sand found on the slides reviewed for pollen support the LOI data in this regard. Coarse-grained material, such as sand, can be generated by landward erosion (Meyer 2013), and high levels of iron, titanium, and potassium support that this sediment likely came from a terrigenous source (Wei et al 2003). For this reason, this environment was interpreted as a relatively landward marsh.

XRF analysis detected a rise in sulfur from ca. 1,200 Yr BP (190 cm) to about ca. 950 Yr BP (150 cm), an element consistent with marine environments (McCloskey and Liu 2012). Given the high presence of iron, the sulfur concentrations are likely caused by the development of pyrite in an anoxic environment (Oenema 1990). Evidence of pyritization is bolstered by the dominance of Gramineae, a family that includes *Spartina*, a common marsh grass that is associated with pyritization of marshes (Otero and Macias 2002).

Pines and other heliophytes complete a max cycle at the beginning of Zone A, then decline, while Cupressaceae and *Quercus* slowly form a max community after ca. 950 Yr BP (150 cm), as seen in figure 4.6 above. This is thought to represent the onset of a more arboreal area that continues into Zone B. The water in this environment is likely to have become less anoxic toward the end of Zone A, shown by the steep decline in sulfur and general lack of plant material, which may have been broken down by oxygen-dependent biota.

5.2 Zone B: 950-600BP (150-110cm)

Zone B is thought to be a warm, swampy environment indicated by the mud and muddy-peat lithology, salt-tolerant vegetation, loss of terrigenous elements (Fe, K, and Ti discussed above), and loss of coarse-grained sediment. This transformation was likely induced by a warming climate and rising sea levels as discussed below. There is also an initial rise of aboreal vegetation and shade-tolerant plants, which may indicate a lack in cyclonic activity in the Louisiana Basin. This lack of cyclonic activity provides further evidence that climate was warmer during this time period, since warmer climates may be responsible for driving paleohurricanes up the eastern coast of the United States instead of into the Gulf of Mexico (Liu 2004b). Finally, a dip in the LOI around ca. 600 Yr BP, along with a rebound in Fe, K, and Ti, may indicate a major flood, followed by an environment dominated by *Quercus*, Cheno-Ams, and grasses.

Visual observation of the core at Zone B reveals a mud and muddy peat lithology, which is also indicated by a general increase in organics and water content portrayed by LOI. In addition, when the material was examined underneath slides during pollen analysis, very little sand was detected. The deposition of fine-grained material is common for marshes that are closer to the sea, but still in a low-energy environment where fine particulate matter, like clay, is allowed to settle out (Meyer 2013). In addition, the terrestrial elements (Fe, K, and Ti), likely provided by land erosion as discussed above decline through from ca. 950 Yr BP to ca. 818 Yr BP (135cm).

Studies stating that overall sea level was increasing through this time period (Kemp et al 2011) provide still more evidence for a shift toward a more seaward marsh. Still more evidence is entailed by the increase of shade-tolerant plants like *Hydrangea* and *Ilex,* which was likely growing at the edge of the marsh. Higher concentrations of plants to generate shaded environments may indicate uninterrupted growth due to a lack of hurricane activity in the Louisiana Basin. Studies by Mann et al (2009) and McCloskey and Liu (2012) corroborate the lack of cyclonic activity during between ca. 950 Yr BP and ca. 600 Yr BP. This lack of hurricane activity may be indicative of a warmer climate, which potentially causes a shift in the Bermuda High that drove hurricanes to the east coast of the United States instead of the Gulf of Mexico during this time period (Liu 2004b).

A potential flood occurred around ca. 688 Yr BP (120 cm). Elevated levels of terrestrial elements are observed at ca. 650 Yr BP accompanied by a large loss of organics and water; specifically, titanium increases sharply, which is consistent with this kind of disturbance (Woodruff et al 2008). Potassium also increases, which is still another well-recognized as element associated with terrestrial sediment (Meyer 2013; McCloskey and Liu 2012). In addition there is a small mix of all plant genera, but heliophytes appear in slightly higher numbers than they have in the past, which may be caused by disturbances during this event which increased availability of sunlight. This flood could have potentially been caused by increased upstream precipitation, or a paleotempest event which generated enough rainfall to deposit terriginous sand.

The data obtained from this range is near the top of the second Livingstone core. It is interpreted to be the same event as the one that takes place ca. 600 Yr BP at 110cm depth because it may be due to overlap; the spikes in LOI and XRF look nearly identical to each other at each of these depths. The portion of the core between these two events shares the same characteristics, further bolstering the potential that this is due to overlap.

Another interesting event may have occurred around ca. 950 Yr BP, where charred material was located (Figure 4.4). This material may indicate the presence of a fire. An increase in *Quercus* and Gramineae (both of which display some degree of fire resistance) and a decrease in Cheno-Am (which has a low fire tolerance) during that time period may provide further evidence for that event. In addition to these changes, Pinaceae is also non-present, which can be yet another indicator of the presence of a fire (Liu et al 2008). Liu et al (2008) also suggest that increases in *Quercus* and *Ilex* occur after instances of fire, due to increased light availability. This trend is also found in the depths above the charred material found at ca. 950 Yr BP.

5.3 Zone C: 600-220BP (110-45cm)

The beginning of Zone C, from ca. 600 Yr BP (110 cm) to ca. 497 Yr BP (90 cm), is thought to be a return to a more arboreal environment like the one found at the beginning of Zone B. The time period between ca. 497-394 Yr BP (95-80 cm) may represent an onset of more advanced saltwater intrusion, possibly due to a drier climate as discussed below. Finally, another flood event may have occurred around ca. 360 Yr BP, followed by a steady recovery of the marsh from ca. 360 Yr BP (75 cm) and ca. 222 Yr BP (45 cm).

The lithology of Zone C appears to be peaty-mud and peat, both indicators a swamp-like environment similar to the one found in Zone B as discussed above. *Quercus* and Pinaceae, however, are rebounding during the beginning of Zone C from ca. 600 Yr BP (110cm) to ca. 497 Yr BP (95cm). In addition, *Typha* and *Ilex* continue to grow in percentages, which show at least a small margin of salt and shade tolerance, and Cheno-Ams and heliophytes, indicative of a disturbance as discussed above, begin to deplete. These changes may indicate the return to a more arboreal marsh area like the one found at the beginning of Zone B. The XRF data shows lower levels of the terrestrial elements Ti, K, and Fe, and continuous levels of S and Cl. This elemental arrangement was also seen in the more forested marsh environment early on in Zone B, may indicate a recovery from the earlier flood.

The time period between ca. 497-394 Yr BP (95cm to 80cm depth) is marked by a complete domi-nance by Cheno-Ams and grasses, and an appreciable presence of Cupressaceae. The paucity of arboreal flora, except for Cupressaceae, and the increase in grass are indicators of saltwater intrusion (Hoeppner and Shaffer 2008). The XRF corroborates this interpretation with rising levels of sulfur and chlorine. It is postulated here that this may be a drier period for this particular marsh, as referenced by the loss of most vegetation types. Given lower quantities of freshwater, salt water that would normally be weighed down by the overlying freshwater column would be allowed to move up the river system

(Fetter 2001; Hoeppner and Shaffer 2008). This interpretation, however, lacks a firm backing in research, though given the reasons stated above, saltwater encroachment is likely.

Around ca. 360 Yr BP (75cm), a major flood may have occurred. The slides were sandy during this interval, and the notable increase in the terrestrial elements titanium, potassium, and iron indicate that it is likely from a terrigenous source. There was also a major dip in the water and organic content as recorded by the LOI analysis. Flooding, and the resultant upstream erosion and downstream deposition, would account for the increases in terrestrial elements such as Ti, K, and Fe; the high-energy of such flooding would also account for the sand supply. This is accompanied by a gain in the heliophytic Amaranth family, which may have been due disturbances created by the event.

From ca. 360 Yr BP (75cm) to ca. 222 Yr BP (45cm) heliophytes stay collectively high, but are lowering throughout this time period and Cupressaceae is no longer detected. Water content and organics are continuing to increase, indicating a recovery of the marsh following the flood around ca. 360 Yr BP (75cm).

5.4 Zone D: 220BP-Present (45-0cm)

From ca. 360-176 Yr BP (35-45cm), *Quercus* decreases, while grass, the Cheno-Ams, *Fraxinus*, and pines gradually increase. Water and organic content in the sediment decrease slightly at this time, but carbonates greatly increase. The same mixture of terrestrial elements increase and chlorine does as well. It is likely that some kind of disturbance event occurred at this time, possibly a paleohurricane.

During the next interval, which extends to ca. 108 Yr BP (20cm), Cupressaceae and *Quercus* grow in minute proportions, but the Gramineae and Cheno-Ams are collectively increasing. The slides for this section are devoid of sand. At ca. 108 Yr BP (20cm), a large event appears to occur; it contains an increase in terrestrial elements and a sharp decrease in organics and water. All vegetation depletes. The depth corresponds with the arrival of hurricane Audrey, 1957 (Williams 2013). The similar dip at 10cm is likely due to the combined effects of hurricane Rita and Katrina in 2005 (Williams 2013).

The top of the core, representing present day, has a mix of all plant types, including an appreciable number of shade-tolerant arboreal genera. Sea-level rise leads to marsh retreat, but anthropogenic barriers inhibit the marsh's ability to move landward and thus lead to a thinning of the marsh due to loss by submergence (Couvillion and Beck 2013). This inability to retreat would cause the edge of the marsh to move closer to the tree line, leading to a greater representation of arboreal taxa. It is possible that the increased presence of arboreal genera is due to this juxtaposition of the sawgrass marsh with upland forestry, caused by the delta's inland retreat and decreasing land availability for transition. This interpretation is likely considering Landsat imagery 29.9 square miles per year from 1978-2000

5.5 Relative Sea Level Rise

The sea level curve created by Otvos (2004), shown in Figure 1.3 above indicates a rising sea level over the past 10,000 years. This supports the interpretation put forth in the discussion above, showing a slow regression of the study area's marsh. An independent sea level curve was developed for this study assuming eustatic conditions shown below in Figure 5.1. This curve matches findings by Anderson et al. (2013), which also indicates an average sea level rise of 2-3mm per yer over the last 400 years likely due to increased erosion. Anderson et al. (2013) attribute much of this erosive change to anthropogenic influence, which has altered sediment supply and subsidence rates along the coast, and notes that these problems may have been further exacerbated by impacts from hurricanes and tropical storms. This would provide a reasonable explanation for the large jump in relative sea level rise recorded in Figure 5.1 below.

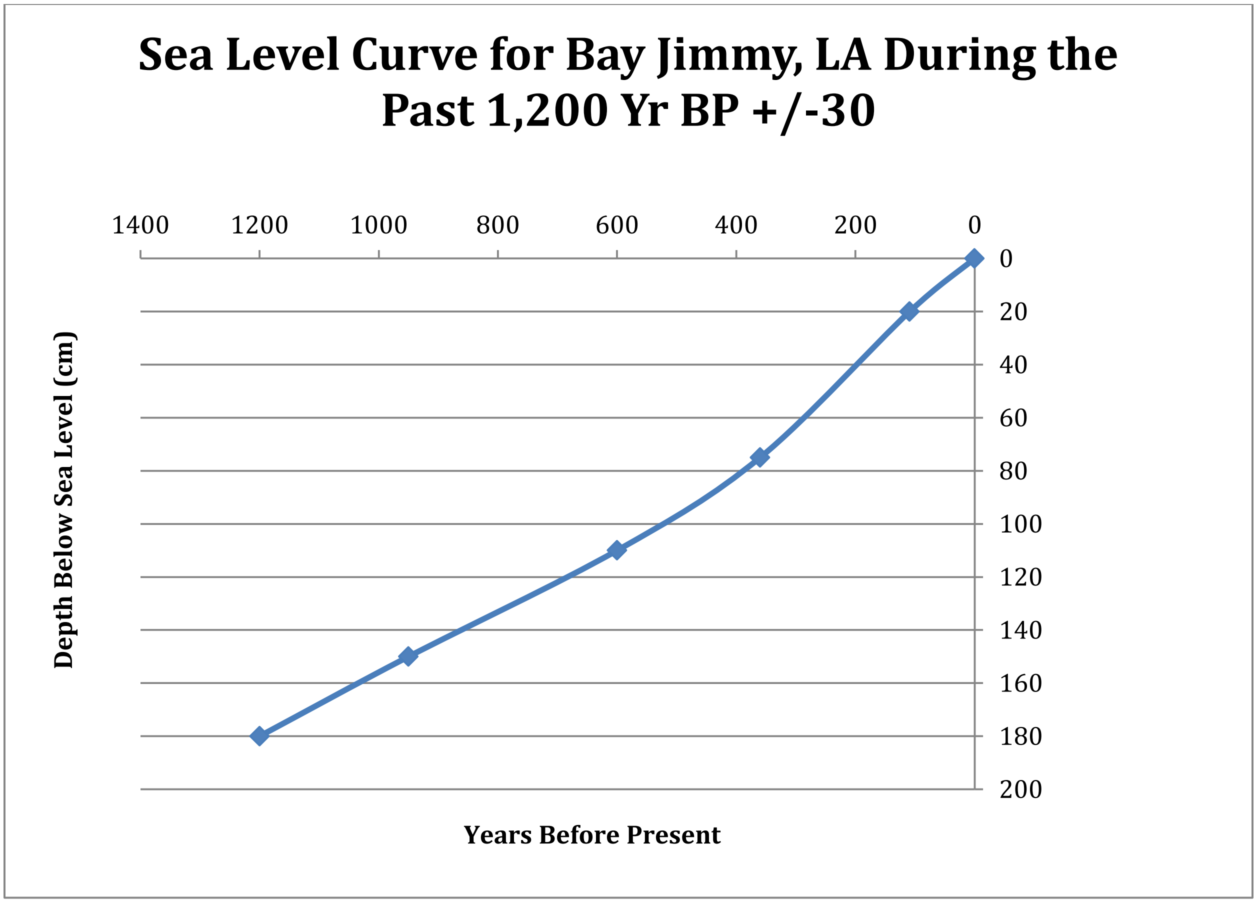

Figure 5.1 Interpolated Sea Level Curve for Bay Jimmy

5.6 Diversity of Flora

The lack of variation in dominant genera was a concern, but a similar trend is seen in a 1996 study by Delcourt and Delcourt (1996), that showed a similar floral community. The duo studied the Mississippi River Valley and displayed the same genera as this survey (*Acer, Ulmus, Fraxinus, Quercus, Pinus, Liquidambar*, and the Cheno-Am families); the study considers these genera, except for *Liquidambar*, to be boreal or cool-temperate taxa. Additional genera and families found in Bay Jimmy are those that are adapted to the frequent inundation and salinity of the Louisiana coast.

6 CONCLUSION

6.1 Summary of Findings

Over the course of the past 1,200 years, Bay Jimmy, Louisiana has had a fairly steady warm and wet climate. Until ca. 950 Yr BP (Zone A) Bay Jimmy was characterized as a marsh with a mud lithology and heavy terrestrial element concentrations such as iron, titanium, and potassium indicating a significant sedimentary input from the land behind it. This marsh was dominated by heliophytic plants, and a high level of sulfur to accompany increased iron concentrations, which likely indicates pyritization induced by an anoxic environment.

From ca. 950 Yr BP to ca. 600 Yr BP (Zone B), the land seems to have retreated from the core location as seen by the decrease in the terrigenous elements iron, titanium, and potassium and the loss of coarse-grained sediments. This change may be due to a warming climate and a general rise in sea level recorded across the Mississippi River Delta by Otvos (2004) and Anderson et al. (2013). A general rise in arboreal vegetation is also indicated by a rise in the pollen counts of Cuprassaceae, *Ilex*, and *Quercus*.

Two major events seemed to have occurred in Zone B. First, charred material found around ca. 950 Yr BP, as seen in figure 4.4, and an increase in *Quercus* and Gramineae (both of which display some degree of fire resistance) and a decrease in Cheno-Am (which has a low fire tolerance), may indicate the presence of a fire. Second, a potential flood occurred around ca. 688 Yr BP, evidenced by a rise in the terrestrial elements titanium and potassium which may have been washed into the marsh by this event, and a rise in heliophytic vegetation, which are known to increase after a disturbance event.

From ca. 600-220 Yr BP (Zone C) may mark first a recovery from the flood event in Zone B, indicated by an initial rise in arboreal taxa *Quercus* and Pinaceae. The years from ca. 497-394 BP may represent more advanced salt water intrusion as detected by a rise chlorine and sulfur by the XRF, and the loss of arboreal flora, except for Cupressaceae, which is salt-tolerant. This change in aboreal taxa plus an increase in grass, which has a low-medium salt tolerance provide further evidence for this change, which may be due, again, to the continued sea level rise noted by Otvos (2004) and Anderson et al. (2013).

In addition to these larger scale trends, another flood may have occurred around ca. 360 Yr BP. This is marked by a drop in water and organic contents as recorded by the LOI analysis, and a rise in the terrigenous elements iron, potassium, and titanium, as well as a gain in the heliophytic Amaranth family, which may have been due disturbances created by the event. The years that follow between 360-220 BP mark a steady increase in water and organic contents, which may indicate recovery from this flooding event.

The start of the final regime (Zone D), which includes modern time, began at ca. 220 Yr BP, where the marsh suffered from a variety of negative environmental impacts. First, a dip water and organic contents around 1957 AD and 2005 AD correspond with the landfall of Hurricane Audrey, and the Hurricanes Katrina and Rita respectively. In addition to these hurricane impacts, a general thinning of the marsh during this time period is indicated by a mix of all plant types, including an appreciable number of shade-tolerant arboreal genera. This juxtaposition of sawgrass marsh with upland forestry may indicate continued retreat and decreasing land availability for transition due to anthropogenic barriers.

6.2 Recommendations for Future Study

The general environmental transitions determined by this study could be further corroborated by additional coring throughout Bay Jimmy. This would also lend further evidence for the more catastrophic events discovered throughout the core such as flooding and fires. If additional cores also indicated a rise in the terrestrial elements discussed above and the same sorts of changes in pollen occurred under similar time frames, flood accounts would be granted a much greater likelihood. If more charred material were found around ca. 950 Yr BP, not only would the fire account in this core gain more support, but the extent to which the fire spread may become more well known.

In addition, forminiferal data could be used to corroborate and narrow a time frame for transitions between regimes. Foraminifera provide a higher temporal resolution because they are not easily transported like pollen, and thus may also assist in the interpretation of floods and potential paleohurricanes.

Finally more corinng may help develop a deeper understanding as to how much anthropogenic barriers may be effecting marsh retreat. This information could be useful for advising human development in the area for the future.

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